The influence of water storage and soldering on types of failure (adhesive and cohesive) in porcelain fused to metal samples.

(An invitro study)

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ABSTRACT

Background: Failure of bonding between porcelain and metal is not uncommon problem in porcelain fused to metal restorations, since the bonding process between metal and porcelain is complex, critical and need great attention to all details mentioned in the literatures according to authors.

Materials and Methods: Forty cylindrical metal (Ni-Cr alloy) specimens were prepared; 8 mm in diameter and 3 mm in height. **20** of these specimens were made in such a way so that it has perforation in the center of 1mm in diameter; the later group is then soldered. All the samples were oxidized, and then sandblasted with aluminum oxide. The ceramic material (vita VMK 95) was applied, the final thickness of ceramic was about 1.5 mm, and then the samples was finished and glazed.

10 of the soldered and **10** of non soldered samples were stored in distilled water for one week, and then shear test was applied for all samples. After the testing, all samples were inspected visually and microscopically to detect the nature of failure.

Results and Conclusion: The result revealed that the non soldered groups have higher percentage of cohesive failure than soldered groups which has higher percentage of adhesive failure, and there is no influence of the water storage on the nature of failure.

Key words: Soldering, Porcelain fused to metal, shear bond test, cohesive and adhesive failure.

INTRODUCTION

Adhesion or bonding is the process of forming an adhesive joint. The initial substrate is called the ***adherend,*** whereas the material producing the interface is generally called the ***adhesive.*** If two substrates are being joined, the adhesive produces two interfaces as part of the adhesive joint. In dentistry, most adhesive joints involve two interfaces [(1)]. Ceramic-metal restorations consist of a cast metallic framework (or core) on which at least two layers of ceramic are baked. The first layer applied is the opaque layer, consisting of ceramic, rich in opacifying oxides; its role is to mask the darkness of the oxidized metal framework to achieve adequate esthetics. As the first layer, it also provides ceramic-metal bond. [(2)] The formation of a strong bond between the opaque porcelain layer and the cast alloy is essential for the longevity of the metal-ceramic restoration. The tensile strength of the metal-ceramic bond should exceed 28 MPa in any system to be acceptable [(3) (4)]. Results from several studies [(5, 6, 7)] that measured the tensile bond strength of metal-ceramic systems were consistent with these concepts. Cohesive failure within the porcelain occurred at 15 to 39 MPa (2200 to 5700 psi), whereas bond strengths measured in shear ranged from 55 to 103 MPa (8000 to 15,000 psi). For many of the shear bond strength determinations, a mixed mode of failure was observed, where adhesive failure at the metal-ceramic interface extended into the porcelain, which fractured cohesively. In more recent years, the focus has been directed toward measurement of porcelain adherence rather than determination of metal-ceramic bond strength. Adhesive failure can occur at the porcelain-metal interface (1) if no oxide layer is present, (2) and at the metal oxide-metal interface (3) and the porcelain-metal oxide interface. Cohesive failure can occur through the

porcelain (4), which is the desirable mode, (5) and through the metal oxide layer (6) and metal.

MATERIALS AND METHODES

Forty metal ceramic specimens were constructed using a specially designed cylindrical stainless steel mold (Figure 1). [9] The mold has a central hole with 6 mm in depth and 8 mm in diameter, and an auxiliary 2.0mm diameter perforation across the mold up to the bottom of the central perforation that was used to remove the specimens using a metallic pin. The set of mold components also includes an 8.0mm diameter, 3 mm thick flat disc used as a spacer for standardization, (this permit standardized 3mm thickness and 8mm diameter for all specimens).

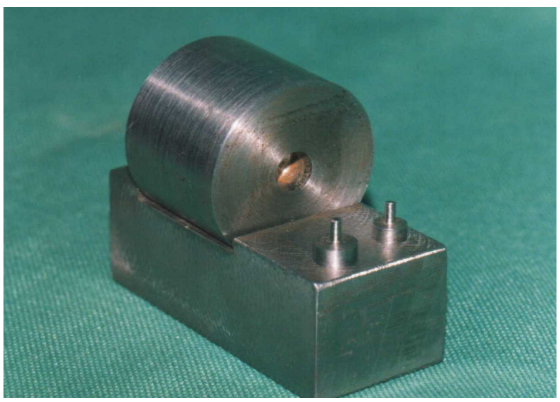


Figure 1: The set of metallic mold.

Type II blue inlay wax was used (Degussa, Germany) was softened by hot wax knife and flowed inside the metal mold with the flat spacer disk inside to produce the wax patterns of group A (figure 2) (control group without perforation), and with pinned spacer disk inside the mold to produce the wax patterns of group B (test group with perforation in the center of 1 mm diameter) (figure 2). The wax pattern then was sprued, invested using Phosphate bonded investment (Gilvest, Hoyermann Chemie GMBH. Germany), burned out, and casted using Ni-Cr alloy (wiron 99, Bego Germany.). The samples were then divested and finished with diamond disks followed by sandblasting with 250 µm alumina particles according to manufacturer instructions.

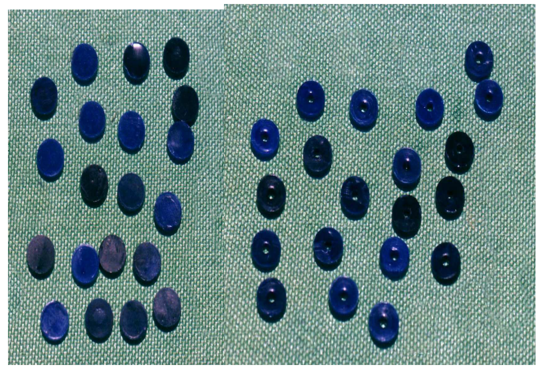


Figure 2: Wax patterns of group A and B

Soldering of group (B) was performed according to the protocol described by Rosenstiel etal [10]**.** A Platinum foil, which acts as a matrix over which solder can flow, was adapted on the undersurface of the test sample and affixed to the casting with sticky wax.

The sample was placed over a fresh mix of carbon-free phosphate-bonded investment in a casting ring until the investment set. A pencil was used to outline all the metal surface of the sample around the hole and limit the solder flow around the perforation (the solder will not attach to the surface over which the pencil is passed). The casting was placed on a tripod and warmed slightly for about 5 seconds, and a small quantity of flux (just enough to fill the hole in the casting) was placed into the hole. A rod of high-fusing white ceramic solder (Wiron soldering rods (Bego, Germany)) was placed over the hole. The casting was heated by torch until solder flowed in the area. All test samples were soldered by the same investigator, and then the samples were finished with finishing kit and sandblasted. The finished metal samples of both groups figure (3) were ready for ceramic application. Ceramic application was done by the use of specially designed syringe for standardized ceramic thickness for all samples. Vita VMK95 ceramic material was used; the final ceramic thickness was 1.5 mm.

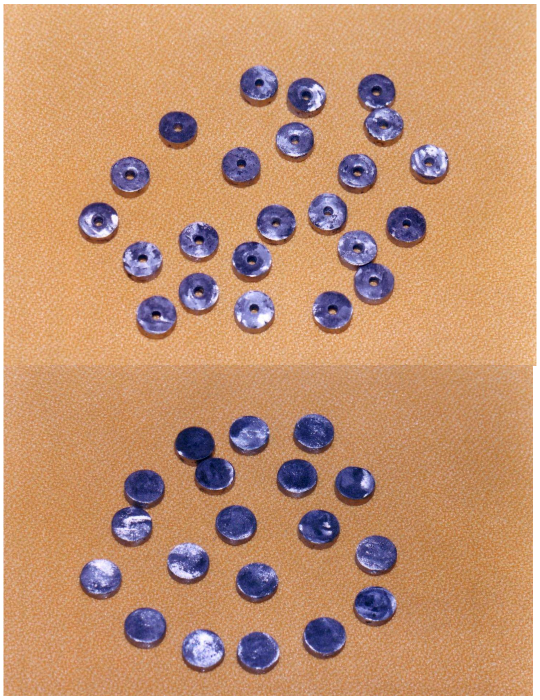


Figure 3: Finished metal samples

10 samples of the group A, and 10 samples of the group B were stored in distilled water at room temperature for one week period.

The sample grouping is as follows:

A1 10 samples not soldered and not stored.

A2 10 samples not soldered and stored.

B1 10 samples soldered and not stored.

B2 10 samples soldered and stored.

All samples were subjected to shear bond test evaluation using Instron testing machine (Instron Corporation 1195 England), with extreme care to place the testing knife on the metal ceramic interface exactly, the samples were loaded until the ceramic is separated from the metal then observed by two practitioners using naked eye and light microscope at magnification power of 10x.

RESULTS:

The percentage of cohesive\adhesive failure was variable for tested groups (table.1), most of the debonded porcelain samples were covered with dark gray oxide layer with variable thicknesses especially in the adhesive failure group (fig.4).

For the cohesive failure group, the failure mostly occurs through the opaquer layer. The remaining opaquer layer covers the entire metal surface in most instances (fig. 5).

Table (1) shows that greater percentages of cohesive failure are present in **A1** and **A2** groups, while the apposite is true for **B1** and **B2** groups. Sometimes the failure occurs in mixed mode with areas of adhesive failure between the metal and metal oxide and areas of cohesive failure in the porcelain. These finding suggest that the non soldered samples had higher cohesive failure than adhesive, while the apposite is true for the soldered samples.

GP.	**Cohesive**		**Adhesive**	
	No.	**%**	**No.**	**%**
A1	7	70%	3	30%
A2	8	80%	2	20%
B1	2	20%	8	80%
B2	4	40%	6	60%

Table (1) mode and percentage of failure



Fig. 4: Dark gray oxide layer on debonded porcelain.



Fig.5: Cohesive failure with remaining porcelain and opaque layers.

DISCUSION

According to the literatures, there is no test that can be considered as pure test for evaluation of the shear bond strength between the metal and ceramic [8] [11] [12].

However, these shear tests were criticized because of the influence of metal surface texture and the possible effect of the residual stress from mismatches of the coefficient of thermal expansion. There still other types of tests that have been used, however, none of them were considered ideal due to their inherent problems [11] [12].

There are many tests that have been used frequently with the ceramic applied around metallic patterns in a semi circular shape, or applied over a flat metal surface to avoid tension in ceramic [1].

A finite element analysis of the tests used to measure metal-ceramic bond strength (e.g., pull-shear, three-point bending, and four-point bending) by Anusavice et al [8] revealed two major problems with all the tests: the stress varied with position along the metal-ceramic interface (particularly near porcelain termination sites), and there was a lack of the pure shear stress conditions that were considered to simulate the loading expected to cause clinical failure most effectively. Furthermore, the small mismatch between the thermal coefficients of the metal (aM) and ceramic (ac) results in an unknown amount of residual stress at the interface, and an idealized value of metal-ceramic bond strength assumes the presence of a residual stress-free interface.

The results obtained shows that the non soldered PFM samples has higher SBS value than soldered samples.

The debonded porcelain of the fractured samples for soldered groups generally were covered by dark gray layer, which was assumed to be the metal oxide, these observations may be due to over production of oxide layer by the solder material which may result in less bond strength, these finding agreed with that of [13], [14], in contrast to that, the observation of the debonded samples of non soldered groups rarely shown oxide layer on metal surface.

Unfortunately the oxide formation behavior of solder material is not provided in the manufacturer paper which is a critical factor in bonding mechanism.

Also the coefficient of thermal expansion of solder material is not provided by the manufacturer which, if mismatched with that of porcelain, may greatly influence the bonding between the ceramic and metal.

The statistical difference between the soldered and non soldered specimens might also be related to the problems of the soldering technique that can't be avoided like inevitable gas inclusions which is created due to soldering temperature leading to small surface defects , also uncontrolled temperature of the torch flame could overheat the solder and the metal causing excessive oxidation with ion diffusion from the parent alloy to the solder or vise versa which is referred to ion diffusion zone or heat affected zone of the solder joint, it might contribute to lack of chemical homogeneity of the materials and reduction in bond strength [15].

Some researchers [16] noticed that there were a wide variety detected between the intact and soldered specimens, these variation might be due to variability of the technical factors and imperfections during the casting or the soldering procedures.

The amount and concentration of flux materials used may also influence the bond strength because high concentration may results in more flux inclusion bodies occurred, more anomalous crystals may be present, and this will affect the surface quality of soldered area. It's extremely difficult to apply the same amount of flux materials to all samples [17].

Effect of water storage:

Statistical analysis of the data showed that there was no significant influence of water storage on shear bond strength and nature of failure at ***p***-value ($p<0.05$).

These results agreed with that of **Kussano** [18] who found that there was no significant difference in shear bond strength of metal ceramic samples with and without water storage. They conclude that when using appropriate technique, the samples will not deteriorates for up to one year at room temperature.

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